Design – Introduction

Holistic design makes the difference

Fill in the blank. "——— was the ideal choice for this product, because it provides us the thinness and lightness we want in the portable category, great strength-to-weight ratio, and it also provides us some really nice options from a finishing perspective."

If you said "plastic" you'd be wrong, or at least that's what Dan Riccio, VP product design at computers and consumer electronics maker apparently thinks.

Courtesy Tony Deligio
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Why aluminium?

It seems that this manufacturer did a value analysis and saw that the combination of excellent heat dissipation, improved stiffness and strength and the decorative finish possibilities outweighed the additional product cost compared to simple plastic computer casings.

'Value analysis' was probably born in the automotive business. Given the wide choice of materials and processes now available, value analysis of the envisaged component or system is today of highest importance for automotive designers who are seeking to meet the present technical, economical and ecological challenges.

The value of a specific product is inevitably interpreted in different ways depending on the point of view. A straightforward approach is to look for the product which meets all the various technical requirements at the lowest cost, considering both material and manufacturing cost. Another possibility is to express value by maximising the service capability of a product relative to its cost:

Value = (Performance + Capability)/Cost

In some cases the value of a product can be raised by increasing both its functions (performance or capability) and its cost as long as the added functions increase more than the added cost. A third possibility is to evaluate the cost of a component - which provides the necessary function – in terms of an additional component characteristic (e.g. its weight). The results of such evaluations are for example the lightweighting cost, i.e. € per kg weight saved. This approach, however, often requires the simultaneous optimisation of many performance functions in order to obtain the quality and robustness needed for practical applications.

A holistic approach to design will refer to both of these methods in order to compare and select the best solutions at decision points or gates that define the starting point for the next phase of the development process.

Purpose and scope

Design Methodology

Competitive application of aluminium in lightweight automotive structures requires an aluminium-oriented design approach. When substituting heavier materials, in general steel and/or cast iron, it is most important that design &engineering takes into account the differing physical and chemical material properties of aluminium. Furthermore, the effects of the different materials characteristics on the production processes must be considered. But it is also to exploit the full potential of new, innovative manufacturing technologies uniquely offered by the application of aluminium alloys.

A simple material substitution seldom results in an optimum technical and economic solution. There are only few exceptions, for example if one or more of the fundamental properties of the substituting material is the dominant requirement for the envisaged application (e.g. the outstanding thermal properties of aluminium compared to steel in case of a heat shield).

For this reason, automotive designers often start with the definition of the boundaries of the problem (design brief or cahier de charge); the functional requirements of the final product, the cost target, the planned time to market and the likely production concept as well as an idea about the end-of-life strategy. The “design methodology” section will emphasis these design phases as well as outline some of design tools currently used by car designers and engineers.

Due diligence requires the implementation of risk elimination procedures when new materials, processes or analysis techniques are used. Often, a risk assessment model is developed by the experts at the vehicle manufacturer with the collaboration of their key component or process suppliers. Hence, it is now common to include a preliminary value analysis into the risk assessment process. Combining risk assessment and a value analysis can provide valuable insight into features that are, or are not, worth including into the final product. This is the preferred method for designing with aluminium where the choice of the product form, the alloy and the delivery condition are important for the cost and the performance of the final product. For example, simplified value analyses have been included in the two case studies.

Design with aluminium

This section lists and explains some design aspects particular to aluminium in its most often used product forms. The intention is to provide the basic guidelines required for designing cost effective, genuine aluminium structures and components with automotive industry standard practices for low, medium and high volume automotive products.

The more detailed considerations will mainly focus on the design of the car body, but the general approach is also applicable to aluminium applications in other vehicle applications.

In the course of time, the car manufacturers have developed an enormous wealth of experience regarding design, manufacturing and use of car bodies made from steel sheets. Steel sheets in various grades, from highly deep-drawable qualities to ultra high strength steels, are today still the dominating material in the automotive industry. In comparison, aluminium sheets, extrusions and castings are “new” materials and there is a lack of experience in the design and manufacturing of cost-effective aluminium components for automotive applications at least within a significant part of the industry.

Aluminium design for functional performance

Designing structures and components for optimum and predictable in-service performance is the quest of vehicle manufacturers and their component suppliers.

Best practice design requires knowledge of how to exploit the special properties of the chosen materials and fabrication technologies in order to achieve the desired performance targets. This section focuses on some design considerations taking into account the specific characteristics of aluminium alloys and their influence on the:

- structural stiffness and strength,
- crashworthiness,
- fatigue life,
- corrosion avoidance and protection strategies for mixed metal structures,
- failure prediction, and
- end-of-life vehicle treatment / recycling

of the envisaged product.

Aluminium design for cost optimisation

Material and semi-finished product forms must be selected early in the design phase so as to optimise the overall cost, weight and most suitable production technology for the required volumes. Investment costs and piece price can be significantly influenced during the design process, i.e. by the shape and dimensions of the individual components, the joining requirements, etc. Most important is the selection of appropriate manufacturing processes. Significant cost reductions can be realized by the application-orientated selection of design principles and fabrication technologies, in particular by the exploitation of all possibilities offered by the aluminium extrusion and high pressure die casting technologies with respect to part integration and reduction of tooling cost.

This section provides some guidelines for the identification of the best starting point for an economic design with aluminium.

Case Studies

This section contains case studies that identify the most important aspects of aluminium products and properties that should be considered in the design process to maximise the performance and minimise the cost of implementation.

In some cases existing components are examined in order to identify validated transferable design principles. Future development potential is assessed by considering the capabilities of new design tools, manufacturing techniques and alloy capabilities.

Currently, two case studies are available, i.e. “Crash management system (CMS)” and “Bonnet & boot lid”.

Disclaimer

The information in this publication is general in nature and is not intended for direct application to specific technical or scientific projects. The European Aluminium Association cannot be held liable for any damage, costs or expenses resulting from the use of the information in this publication.

For additional information please contact your aluminium supplier to be able to discuss details directly with the relevant experts.